Report of the C-AD Machine Advisory Committee Meeting 15-17 November 2010

1. *Executive Summary*

The C-AD Advisory Committee was presented with material concerning two central topics of polarized-proton-beam developments for RHIC: increased polarization and increased luminosity.

Because the figure of merit scales linearly with luminosity and in forth power with the polarization, the committee appreciates that a detailed discussion of every, even small increase in polarization is worth discussing.

The MAC was impressed by the continuous progress in polarization optimization. BNL's CAD is the world center in high-energy polarized-beam research since many years, has been successful in understanding intricate details of polarized beam dynamics, has invented techniques of polarization optimization and avoidance of depolarizing effects, and has developed polarized source, polarimeters, Siberian Snakes, and other technology essential for polarizing its proton beam. By now, the polarization at 100GeV is up to about 55% and at 250GeV up to about 45%. Plans of improving polarization even further include a large increase in polarized current, a new absolute polarimeter after the booster, quadrupole jumping to avoid polarization reduction at horizontal spin-orbit resonances, new and improved CNI plarimeters in RHIC, improved orbit correction to reduce depolarizing resonance strength, and more suitable tune choices. Combined these effects could lead to an impressive increase of polarization to a value of 70%.

2. *RHIC upgrades*

2.1. Findings

The 2010 Run featured ion operation only. The 2011 run will feature both, ion and polarized proton collisions at 250 GeV, runs at lower energies for Au (100 GeV/nucleon) and Uranium (96.6 GeV/nucleon) ion beams, plus tests for Au collisions at very low energies (2.5 GeV/ nucleon).

The performance of the Au operation in 2010 was a remarkable factor 10 higher than the design value. The possibility of generating anti nuclei in the quark-gluon plasma motivates even further increases in the luminosity for ion operation. The impressive RHIC performance benefitted, among other things, from improvements in the RHIC beam instrumentation over the last years and the implementation of a novel stochastic cooling system.

Studies for the ion beam luminosity optimization identified three dominating limitations for the RHIC performance with ion beams: IBS, performance loss for operation with reduced b* and beam instabilities at transition crossing. Several upgrade options have been identified for the ion operation and the required R&D efforts have been launched: extensions of the stochastic cooling system, operation with the new EBIS ion source, a passive 56 MHz SRF system, and an electron cooling system for low energy operation.

During operation at 100 GeV and 250 GeV, the polarized proton operation reached an average polarization level of 55% and 35% and peak luminosity of L = 50 10^{30} cm^{-2} sec^{-1} and L = 85 10^{30} cm^{-2} sec^{-1} respectively in 2009. While this is an impressive factor above the original design luminosity of L = 10 10^{30} cm^{-2} sec^{-1}, further improvements are needed to reach the performance goal for 2011 / 2012 of L = 150 10^{30} cm^{-2} sec^{-1} with 70% average polarization at 250 GeV beam energy. Studies for the polarized proton-beam operation identified several limitations for the RHIC performance: decrease of polarization in the AGS with increasing proton beam intensities, depolarization during transition crossing in the AGS, depolarization in RHIC during acceleration, beam intensity limitations in RHIC, luminosity-lifetime reduction for small b* values and limitations of total beam-beam tune spread. Several upgrade options have been identified for overcoming these limitations and are well under way: upgrade of the polarized proton source to provide higher beam intensities, horizontal tune jump system in the AGS, acceleration near the 2/3 resonance in RHIC for improved polarization transmission, RHIC beam dump upgrade to be compatible with higher beam intensities, a 9 MHz RF system for acceleration of longer bunches to reduce IBS, and an orbit stabilization system against the '10 Hz' modulations and electron lenses.

Both operation modes, with ion and polarized proton beams, benefitted from the implementation of feedback systems for orbit, tune, coupling and chromaticity. Electron-cloud effects still affect both operation modes and studies are under way for an in situ coating of the RHIC vacuum chamber to mediate the electron cloud effect in the machine.

A new third experiment for the Drell-Yan channel will be installed in IR2 in RHIC. Three options are under study for the implementation of this experiment: proton collisions with an external target; collisions between the two proton beams; and collisions of one of the proton beams with an internal gas target.

Polarized ^{3}He and deuteron beams are interesting options to study the polarized neutron. ^{3}He beams require operation parameters that are much closer to the nominal proton beam configurations and might therefore be significantly better suited for the operation in the RHIC collider. R&D efforts for a ^{3}He source have started on the conceptual level.

Comments

Several topics are not yet fully understood: the decrease of polarization during runs at 250GeV, quantitative details of several depolarizing resonances, and the lower than expected luminosity performance for reduced b* values at 100GeV.

It did not become clear to the committee whether ^{3}He or Deuteron beams would be preferred probes for the neutron. However, it was illustrated that providing polarized Deuterium beams in RHIC would be much harder than ^{3}He, and the later should therefore be considered as a baseline. It should be clarified if Deuterium beams have sufficient advantages to be studied as an alternative.

Options for surface scrubbing with beam to mediate problems with the electron cloud effect might not yet have been fully developed and the MAC encourages the RHIC operation team to look further into beam scrubbing runs. RHIC operation featured only one short test period with scrubbing runs in 2009. which showed that surface conditioning is not long lasting. This has not yet been understood. This deconditioning effect should be fully understood before decisions are taken for a new coating of the RHIC vacuum chambers. Without this understanding, it is not clear how one can be sure that coated Cu surfaces can better maintain low secondary emission yields after beam scrubbing runs than the existing stainless steel chambers. In any case, the proposal to develop a procedure and machinery for in situ coating of the RHIC vacuum chamber seems to be challenging (the proposal to pull an in situ coating machine through the RHIC vacuum system bares the risk of getting stuck in the vacuum system during the coating procedure; bares the risk of damaging the vacuum system surfaces, RF fingers and transition pieces).

Investment into an electron lens seems to be strategically important as RHIC might face operation with higher intensity and with up to three head-on proton beam collisions.

Overall, the C-AD seems to have planned for a well thought out upgrade that has the potential of further increasing the performance of ion-beam operation and to achieve the target luminosity for polarized proton operation at 250 GeV beam energies. The design polarization at 100GeV seems achievable, while maintaining high polarization to 250GeV may require more detailed understanding of resonance strengths, orbit alignment, and stabilization.

2.2. Recommendation

- Explore alternative scrubbing run configurations and try to understand why the secondary emission and/or desorption yield did not remain reduced for an extended time after scrubbing.
- Organize a workshop for polarized ^{3}He operation not only with the accelerator team but include HEP experimentalists in these discussions.
- The beam-loss rate and the luminosity lifetime under beam-beam forces has to be understood sufficiently. Devise a systematic machine study program for beam-beam effects in proton-beam operation and try to better understand beam-beam limitations for the proton beam operation.
- Full mitigation of the ’10 Hz’ orbit oscillations driven by the triplet magnet is a prerequisite for a proper understanding of beam-beam limitations. Fully implement the proposed correction system.
- Intensify spin tracking to include a realistic model of the accelerator and its closed orbit.

3. Polarization

3.1. Polarized Source Upgrade

Findings

The polarized H- source at BNL is world leading and one of its kind since many years. It has long been propagated that OPPIS technology is the most suitable way to higher polarized currents, and BNL’s gun group has reproducibly generated on the order of 1mA polarized H- current at up to about 85% polarization, and has demonstrated a credible strategy for further increasing the current by a factor of 10 and boosting the polarization by another 5%. The strategy of producing a high current H0 beam in the Fast Atomic Hydrogen Source before the Helium ionizer cell and the polarizing Rubidium cell has been shown to work in a successful collaboration with BINP Novosibirsk. And also the benefit of a new solenoid for these cells is well supported.

The development of an improved polarized H- source is justified for four reasons:

a. Increased polarization at the source directly translates into larger polarization at high energy.

b. It is currently estimated that RHIC can utilize up to about a factor of 2 more proton current.

c. The luminosity can benefit from smaller emittances, which can be produced by scraping a beam with increased current. It is not yet clear how large the emittance growth would be in the acceleration chain, and therefore at what point scraping has a diminishing return. But some amount of scraping currently seems beneficial.

d. Reducing the emittance by scraping reduces the strength of intrinsic depolarizing resonances. The most relevant intrinsic resonances are currently the horizontal resonances in the AGS, which will be overcome by tune jumps and may therefore not further benefit from scraping. But scraping would be beneficial for other resonances, including snake resonances in RHIC.

An absolute polarimeter will be added at 200MeV to reliably optimize polarization out of the OPPIS.

The H- OPPIS has been developed and optimized for years. A source for polarized Helium-3 has been developed to a much lesser extend; only an initial concept exists, which is scaled from existing cells and would inject polarized Helium-3 into the EBIS.

Comments

While the committee observes that a 10 fold increase in current for the OPPIS may be more than what can be used beneficially for RHIC in the near future, we support the ongoing effort of increasing the current as much as possible at this time for the following reasons: This source research is in itself a world leading R&D effort, an overhead in current can be beneficial in the long run, and other polarized experiments in the future may benefit from this improved technology.

While it is currently not known in how far AGS can take advantage of a higher brightness beam, today’s intensities should allow an analysis by

a. running with larger unpolarized beam currents and studying output emittances as a function of scraping at injection energy.

b. studying the output emittance as a function of scraping for polarized beam, which today is scraped by up to 70%.

Developing the concept for polarized Helium-3 out of the EBIS could be a significant research project. Once a timeline for polarized Helium-3 in RHIC is known, this source development needs resources. This will include the development of a polarimeter for 2MeV polarized Helium-3 beam.

Recommendations

- Study whether AGS can take advantage of a higher brightness beam.
- Study polarization increase at RHIC after more scraping, evaluating how much the total polarization loss depends on emittance. This can be very time and cost intensive, but it would help to find run parameters and procedures that optimize the figure of merit $L*P^4$.

3.2. Quadrupole Jump System in AGS

Findings

With only partial snakes available at the AGS, horizontal depolarization resonances contribute a non-negligible loss of polarization (~5%). To recover the lost polarization due to these horizontal resonances, a set of two tune-jump quadrupoles are installed to increase the resonance crossing speed by a factor of 4 (Q_x jump 0.04 in 100 us). A preliminary test of this system showed some evidence of polarization gain up to $G\gamma = 7.5$.

However, triggering the jump quads was found to cause a large vertical emittance growth. With Q_y very close to 9, the cause was traced to a large β_y beat driven by a 6th harmonic of a horizontal closed orbit coupled with the sextupole distribution. This study was then convincingly confirmed with a set of experiments. With proper control of the 6th harmonic of the horizontal closed orbit, the β_y beat was removed, and the jump quads are now available for practical runs.

It was found that during the beginning of a ramp, Q_y changes quickly due to error fields. This behavior caused crossing of depolarization resonances because the vertical tune leaves the window [0.9,1.0] which is kept free of first-order resonances by snakes. It is expected that some loss of polarization has been associated with this problem.

Comments

The tune jump system has been prepared well. The test runs and the successful control of vertical β_y-beat using 6th harmonic horizontal closed orbit is impressive and has generated successful and very useful outcome. It looks ready to be used to gain up to 5% polarization by overcoming the horizontal resonances in the AGS. Attention will be needed to control for emittance growth from mistiming or mismatch of the two quads.

Recommendations

- Prepare for the systematic study of polarization effects in the AGS using the tune-jump quadrupoles. This study is to be done together with an analysis of polarization effects such as emittance and beam intensity dependence, and snake resonances.
- Pay attention to timing and strength matching of the two quads. In addition, careful orbit steering through the centers of the quads may prove necessary for a clean operation.
- The Q_y change at the beginning of a ramp should be controlled as soon as possible. The cause of this behavior should be found.

3.3. Acceleration in RHIC near 2/3 Vertical Tune

Findings

The 250-GeV polarized proton operation suffers from significant polarization loss during acceleration, as well as from limited polarization lifetime in store. One goal of the RHIC upgrade program is to reach a polarization of 70% at all energies.

At 250 GeV, the polarization in store has deteriorated over 8 hours of store time by up to a factor of 2 (worst case), from 50% to 25%, based on CNI measurement. This depolarization is related to the set up of the spin rotators, and depends on the spin tune and the spin tune spread near weak snake resonances. It is mitigated by tuning the spin rotators, by controlling the optics between spin rotators, and by properly setting up the snakes.

Above 100 GeV the strength of some snake resonances is doubled or even tripled. Three particularly strong resonances are expected to dominate the depolarization on the ramp, where the polarization transmission is insensitive to the horizontal tune, but varies greatly with the vertical tune. The depolarization on the ramp is worse in the yellow ring than in the blue ring.

The planned acceleration of the blue beam near the vertical Q_y = 2/3 resonance alone should increase the polarization transmission to 250 GeV and may reduce polarization loss during store. This tune is chosen as there is no noticeable snake resonance and machine measurements with moderately intense beam have indicated close to 100% polarization transmission. The β^* squeeze was delayed since it has a negative effect on polarization.

In preparation for the 2011 run, a test with Au beam during 2010 has explored acceleration to 100 GeV near the Q_y = 1/3 (not 2/3) resonance with a completely different lattice. The test demonstrated robustness and reasonable chromaticity at a vertical tune of about 0.005 from the third order resonance. In simulations the dynamic aperture for 250-GeV protons at a vertical tune of 2/3 is roughly two times better than the one for 100-GeV Au ions at a tune of 1/3. It is thought that if Au can be accelerated to 100 GeV then there should be no problem for the acceleration of polarized protons.

The proton operation close to the 2/3 resonance was initially prevented by a glitch in the power converter at the change of the acceleration rate. This problem has by now been fixed.

While it is planned to operate the Blue Ring close to Q_y = 2/3, a different working point equal to the original design value (0.18, 0.19) is considered for the Yellow Ring. This working point should have weaker intrinsic resonances and a good dynamic aperture. It had been abandoned in the early days of RHIC due to problems with tune/coupling control, which should no longer be a problem thanks to improved feedback performance, and the cure of a power-supply glitch. A tune closer to the integer is also expected to be better for spin dynamics.

Comments

Large error in the polarization measurement 10% causes problems in operation and in optimizing the polarization transmission.

Delaying the squeeze to the end of the acceleration reduces losses and might also improve the polarization transmission.

Choosing two different new working points for the two rings has the potential to improve the polarization for either, and will allow comparing their relative merits.

At the same time the new working points will avoid the pi-mode beam-beam resonance and might result in improved Landau damping for colliding beams.

The simulated dynamic aperture is close to zero for Au ions at the tested working point while the ion beam was successfully accelerated. This may raise some concern about the validity of the underlying machine model.

Recommendation

- Perform weak-strong and strong-strong 6-D beam-beam simulations for the planned tune working points.
- Optimize operational cycle with regard to polarization, e.g. squeeze after acceleration. Benefit from, and push for, improved polarization measurements.
- Improve optics control by beam measurements and refined modeling, including snakes and spin rotators.
- Study effect of beam-beam collisions on polarization at 250 GeV.

3.4. Tour of EBIS

Findings

The committee toured the EBIS and the optically pumped ion source and its test bench. These new sources are impressive accomplishments by the RHIC team. They should provide excellent flexibility to optimize the downstream operations.

The EBIS ion source is presently being commissioned. It can be operated with electron currents up to 10 A, but the power in the electron beam is still limited. The linac after the EBIS consists of an RFQ and IH.type structure. The rf structures were installed in the first half of 2010, they are presently working up to expectations. No serious problems were faced during the commissioning. First helium beam from the EBIS has been injected into the booster after acceleration in the linac to 2 MeV/u, but not yet been accelerated in the booster. Beam acceleration in the booster is planned in the coming weeks. A preliminary run with gold ions reached 10% of design current. CD-4 was received in September, 2010. Uranium runs are expected in run-11.

The existing polarized H- source will be modified for the proposed intensity increase. Various upgrades have been preformed in preparation of the planned intensity increase. A test bench is in operation with a prototype of the new proton injector source developed at BINP Novosibirsk. The test bench is ready for installation of the new injector source presently manufactured in Novosibirsk.

The upgraded H- source will produce a high intensity of 5-10 mA with 85-90% polarization. It is proposed that this great advantage be used in the optimization of luminosity and/or polarization through proper beam scraping in the booster.

Comments

The commissioning of the linac seems to progress very well. The operation of the source with different ions still requires some effort, particularly with respect to tuning the system to the different mass to charge ratios of the ions. So far no uranium beam has been produced, but there are clear plans for uranium beam in RHIC.

The very substantial factor of 10 gain of H- source intensity by the upgraded source lacks a consistent plan of its effective downstream usage. There is not yet a systematic effort to fully optimize this opportunity, taking into consideration of emittance-intensity trade-off at the booster scraping, polarization dependence on emittance and intensity, space charge at Booster and AGS, beam-beam limit at RHIC, and the beam dump limit at RHIC, etc. A preliminary exercise of this optimization seems to indicate a rather limited usage of this gain of factor of 10 from the source.

Recommendation

- Test EBIS and linac as soon as possible to gain experience in operation with various ion species, particularly first uranium beam should be accelerated.
- To fully utilize the capacity of the upgraded H- source, it is suggested to examine the operational parameters again and formulate an optimized set of parameters that includes source capability, booster and AGS transfer line limits, emittance-intensity trade-off, booster and AGS space charge, RHIC beam-beam, and RHIC beam dump capability. A set of parameters along the chain of accelerators should be established that takes full advantage of the source upgrade.

3.5. Orbit Effects on Polarization

Findings

Polarization level is strongly influenced by errors including closed orbit effects. This is an involved subject and rightfully occupied a substantial effort at RHIC. A lot has been learned in this effort and significant progress has been made.

It was found that the polarization at 250 GeV sometimes decays significantly during a store. This decay was then found to depend sensitively on the setting of the spin rotators. By orbit control and careful setting of the rotator parameters, this decay can be put under control.

Depolarization in RHIC is mainly driven by snake resonances, which are located at $Q_y = (2m+1)/(2n) +- (\Delta\nu)/n$ where $\Delta\nu$ is the spin tune shift from the nominal value of ½. Without orbit errors, only odd-n resonances are driven, but even-n resonances can be driven by orbit errors. The spin tune shift $\Delta\nu$ can be driven by various sources, and once driven, they effectively widen the resonance widths. A careful survey was made to find these various sources of $\Delta\nu$ for RHIC, and most of them are of the order of ~0.001-0.01.

A detailed set of measurements of RHIC polarization as a function of Q_y was performed, mapping out these snake resonances. Both even-n (e.g. $Q_y = 11/16$) and odd-n (e.g. $Q_y = 7/10$) resonances were found. The resonance widths effectively were ~0.01-0.1 level, much wider than either the expected theoretical estimate or the computer simulation values.

Orbit control has been improving with some recent new developments:

a. 10 Hz orbit oscillations will soon be suppressed by a feedback system consisting of 12 correctors and 36 BPMs. Without correction, this 10 Hz orbit is expected to have a strong effect on luminosity, but it may also affect the polarization.

b. In run-10, a set of BPM offsets were found to have reversed signs. This has since been fixed.

c. Vertical realignment is under way of whole ring.

d. Orbit control during the ramp (with tolerance of 0.3 mm rms) is being improved.

e. Tune, coupling, chromaticity are feedback controlled during ramping.

All these developments are expected to help the next 250 GeV polarized proton runs.

Comments

Simulations are an important tool for polarization study. Much more efforts are needed to continue to sharpen this effort and to gain insight of polarization physics. The committee is pleased to hear that there has been an increase of expert manpower and emphasis on this important effort.

The measured snake resonances versus Q_y have not been fully understood. Every effort should be made to do more simulations and studies to identify the source of the discrepancy.

This discrepancy casts an uncertainty on the polarization upgrade program which largely relies on the predictive power of these simulations. The snake resonance data should be confirmed and benchmarked by the polarization simulation codes. The discrepancy needs to be resolved.

Recommendation

- The sensitive dependence of polarization decay during store on the rotator settings should be understood. Mechanism of this problem as well as ways to cure it should be identified.
- It is suggested that the polarization simulation effort be made one of the next highest priorities. It is suggested that the next step is not only to benchmark between existing simulation codes, but more importantly to develop a realistic RHIC machine model with real predictive power. This will include, but not limited to, efforts to enhance simulation physics capabilities such as to include orbit effects in spin rotators and chromatic effects.
- Snake resonances should be estimated analytically as well as obtained by simulations. It is suggested to incorporate the existing analytical tools into one of the present calculation programs.

3.6. Polarimeter Upgrades

Findings

RHIC has a polarized Hydrogen target as slow absolute polarimeter with better than 5% accuracy, and Coulomb-Nuclear-Interference devices as faster relative polarimeter in each ring. CNI gives information about the vertical and the horizontal component of polarization by analyzing the angular distribution of low angle scattering in thin carbon strips of only a few 10nm thickness, which are produced at either TRIUMF or BNL

However, AGS currently only has two relative polarimeters, also of the CNI type, and an absolute polarimeter currently under development will help to optimize injected polarization at 200MeV after the booster.

Several years ago, the CNI polarimeter of AGS was used during the ramp with an accuracy of about 5% by leaving the carbon scatterer in the beam halo. This capability has been lost but will now be reactivated.

Polarimetry has been developed impressively, allowing measurement of the polarization as a function of horizontal and vertical phase space amplitudes by scanning the CNI foil through the beam. The beam profile itself is obtained simultaneously. This information is regularly used to weigh the polarization in a phase space volume by the amount it contributes to the luminosity.

The RHIC CNI polarimeters are to be made more sensitive and faster by upgraded electronics, which has been tested in the AGS under conditions that simulate RHIC beam in terms of intensity and bunch spacing. These tests have so far been successful and will continue. Two such upgraded polarimeters will be installed in each of RHIC's rings.

Comments

Polarization measurements are obviously the basic requirement for optimizing polarization in RHIC. The committee has again been impressed by the understanding of polarization dynamics at BNL and the strategy of faster relative polarimeters, checked by a slower absolute polarimeter has worked out well.

Recommendation

- We recommend proceeding as planned with the improvement of these essential diagnostics devices.

3.7. Operation with Polarized d and 3He

Findings

The low anomalous magnetic moment of a deuteron makes its spin very difficult to manipulate in an accelerator. In particular it is not clear how to build a rotator for longitudinal polarization of deuterons. A partial snake with very low strength, 0.16%, from 4 helical dipoles could be constructed, but the effectiveness of so weak a snake is questionable. One possible viable scenario could be when deuterons are vertically polarized throughout the accelerator journey from source to the IP in RHIC, and possibly useful for their transverse spin studies. Polarized deuterons could probably be provided with a new ring in figure-8 configuration.

On the other hand, He3 has a sizable anomalous magnetic moment, thus much easier to spin manipulate in an accelerator, while they are also preferred by the nuclear physicists since a polarized 3He would be the nucleus closest to a polarized neutron. For 3He the snakes would work at lower field than for protons, and indeed there are more snake-field options for 3He than for protons.

A proposal was made by the RHIC team to provide a He3 polarized source for RHIC. The polarization is based on a metastability exchange technique, with a polarization of 80-90% designed. It could be incorporated in the EBIS. In addition, a Lamb-shift polarimeter is envisioned at 2 MeV.

There is no code that calculates the strength of snake resonances, except for one code from Sateesh Mane which considers an ideal snake.

Polarized 3He particles will experience more and stronger resonances than the protons, due to a larger value of $|G\,\gamma_{max}|$. There are two strong intrinsic resonances at the highest 3He energies approaching 500 GeV. The highest reachable energy at RHIC is therefore not yet clear.

Intrinsic resonances for polarized He3 in AGS and in the booster have been surveyed.

One particular feature of 3He is that the beam is below transition at injection into RHIC, which is different from other nuclei species. However, polarized protons cross transition in the AGS without any problem.

The situation in the AGS is complicated as one will need to “tip over” the spin axis in AGS with a warm snake. The cold snake is very slow and cannot ramp. In addition, a solenoid snake is required in the booster to AGS transfer line. Another point to consider is the AGS to RHIC transfer line, for which a spin-preserving solution exists.

The transverse polarization for protons is already being measured at STAR and PHENIX. A workshop on 3He polarimeters is proposed. One could probably continue to use CNI and experimental polarimeters. However, the H jet cannot get the absolute calibration for 3He. An absolute calibration is needed. Elastic scattering of a polarized 3He beam off a polarized 3He target would be one approach, for example. When nuclear and electro-magnetic cross sections are of the same order of magnitude an analyzing power of ~3% is typical.

Equipment for a polarized 3He source will be prepared in at least 2 years’ time either at BNL or Bates. One could then inject polarized 3He particles into the EBIS.

Synchronization issues as expected for 3He or deuteron beams colliding with protons already exist with gold ions, for which there is about 0.5% energy difference with respect to the protons.

Comments

Polarized He3 source program as proposed by the RHIC team looks feasible and ready to proceed. The committee has not heard however how a He3 project will be useful for nuclear physics studies as a provider of polarized neutrons, as compared with a polarized deuteron source although the technical difficulties of a polarized deuteron beam in RHIC is well taken.

Solving the problem with polarization loss for high-energy protons would prepare the path for 3He beams, which will suffer from even stronger resonance strengths.

Recommendations

- Solve problems with 250-GeV proton polarization to prepare for 3He.

- Do spin tracking for 3He to address the question whether a dual full snake can preserve polarization in the presence of the strong intrinsic resonances or if the last two resonances, at highest energy, are causing significant polarization loss. The feasibility of crossing the last strong resonance near 500 GeV should be resolved.
- Study the possibility of colliding vertically polarized deuterons.
- Organize the proposed workshop on 3He polarimeters.
- Investigate preservation of 3He polarization in the EBIS.
- Communicate with nuclear physics community and establish a comparison of polarized deuterons versus polarized He3. This comparison should include the nuclear physics need as well as accelerator technical considerations.

3.8. Beta-star limits

Findings

An attempt has been made to estimate the minimum β^* value at 250 GeV, where there had been only one run so far with β^* = 0.7 m, from experience from operation at 100 GeV with three different β^* values (3.0, 0.9, and 0.7 m).

The luminosity evolution is characterized by a double exponential fit, with two time constants. The longer time constant of typically 10 h represents the decay of 80-90% of the luminosity. The shorter time constant represents the initial “transient” and is of order of 1 h.

The luminosity decay comes from both intensity loss and emittance growth. These losses and emittance growth occur only with colliding beams. Both planes and both beams are affected about equally. The proton luminosity decay at 100 GeV is much faster than the burn off, and it is explained neither by IBS nor by the vacuum. The proton bunches get longer during the store, which also contributes to the luminosity decrease.

With a reduced β^* of 0.7 m in Run-9 the long time constant was only 6 h compared with the 10 h at 0.9 m in Run-8. The total beam-beam tune shift in Run-9 had been 20% higher than in Run-8 (0.013 versus 0.011), despite smaller bunch intensity, due to a significantly smaller transverse emittance. The initial peak luminosity in store scales with the product of bunch intensities.

It is argued that the long luminosity lifetime does not depend on the beam-beam parameter.

Various changes have been made to the Run-9 configuration to explore the cause of the poor luminosity lifetime in Run-9 (varying #bunches, bunch intensity, RF voltage increase, β^*). A 9h RF ramp to 200 kV/cavity improved the lifetime to about 9 h for 80% of the beam, which is slightly worse than 10 h for 90% in Run-8, but better than 6 h for 90% of the beam with a fast RF ramp to 150 kV/cavity. Unsqueezing to 60 cm improved the lifetime to 11 h but only for 60% of the luminosity. Larger transverse emittance also improved the lifetime, to 8.3 h for 95% of the luminosity.

Reloading the optics from Run-8 resulted in the same loss level as for Run-8 in the first few minutes of collision, which has been taken as a proof that the problem in Run-9 has not been due to an additional external noise source.

Attempts with gold beams at running with β^* = 0.6 cm revealed an insufficient momentum aperture for gold. This, together with the lack of an accurate optics model, led to the failure of a beam-based measurement and correction of the nonlinear chromaticity. The β^* had to be backed off to 0.7 m as a result. Primarily off-momentum particles were lost, which is believed to be due to chromatic β beating. There is a 20% on-momentum β beat, the origin of which is not understood. There is a pi/2 phase advance between IRs 6 and 8 to cancel most of the off-momentum β beating from the low-β insertions.

IR multipole correction in IR6s and 8 includes sextupoles, skew sextupoles, and octupoles, the settings for which are based on measured tune shifts from orbit bumps in the IR triplets. An additional 10- and 12-pole correction is optimized empirically based on the observed beam loss rate.

Power supplies and leads allow for minimum β^* of 50cm at 250 GeV. A smaller emittance beam samples smaller triplet multipoles. In this sense a β^* of 90cm at 100 GeV is equivalent to β^* of 36 cm at 250 GeV, and a similar dynamic aperture is expected when the nonlinear chromatic effects are corrected.

Comments

There is no obvious show stopper that would prevent 250-GeV proton operation at 0.5 m β^*.

The fact that the initial peak luminosity scales with the product of bunch intensities is expected and cannot be taken as evidence for the absence of a beam-beam limit. The latter appeared to be visible on the long time scale.

The RF ramp affects the luminosity lifetime, which suggests that the hourglass effect - and/or a small residual crossing angle - and the associated parameter modulation in conjunction with synchrotron motion may be important ingredients for the luminosity degradation. Emittance and beam size seem to have a strong impact on the luminosity lifetime.

The double exponential fit may obscure the physical origin of the luminosity lifetime. A fit to a model formulae or a combination of model formulae would be preferred.

Instead of quoting long and short lifetimes and the corresponding fractions of the beam, which often change in contradictory and inconclusive manner (e.g. short lifetime increases while long lifetime decreases in response to a parameter change), it might be better to compare the integrated luminosity.

No luminosity evolution for the reloaded Run-8 optics was presented and the initial losses shown should be related to the short time constant rather than to the long time scale. From the data presented it did not become clear that the long lifetime value was restored by reloading the old optics.

The relevance of the gold-ion beam measurement is not clear, as the optics, working point, and momentum spread were different from the protons. Whether or not the available optics model is accurate and allows for efficient correction appeared controversial.

It is not clear why the model does not correctly predict the off-momentum β beating if the latter is due to the squeezed IRs.

Optics modeling and correction work will also be helpful for preserving polarization.

A summary of the basic optics configuration (Q, Q' and c) is still missing. It will be helpful to analyze values and fluctuations of these parameters.

The fitting of luminosity lifetimes should be done on a bunch-by-bunch basis. It would also be beneficial to look at the evolution of the specific bunch luminosities in order to decouple the luminosity degradation due to intensity and beam size related effects.

Configuration changes have to take into account Q', c and β-beat and the RHIC 10 Hz ripple as potential causes for problems. After a further discussion of the 10 Hz orbit ripple effects it is not clear to what extent the observed performance limitations for small β* values are related to the 10 Hz orbit oscillations (tune modulation of the order of 10^{-3}, modulation of the beam crossing angle and the beam overlap at the IPs).

It was not clear what strategy was used for fixing the machine tune: either fixing the tune before the beam-beam is turned on or after. The strategy will affect what resonances are seen and crossed as the beam intensities decay over a run.

Recommendations

- An effective correction of the 10 Hz orbit oscillation due to the triplet vibrations is the pre-requisite for a proper understanding of the luminosity lifetime dependence on various beam parameters. Without such a correction, the luminosity lifetime might just be dominated by effects originating from the 10 Hz orbit modulation (e.q. tune modulation and tilt and offset modulation of the two beams at the IPs).
- Establish a good optics understanding and, in particular, an accurate model for the on- and off-momentum optics which correctly predicts the off-momentum β beating, and allows pre-computing its effective correction. Also compute the dynamic β beating induced by the collisions.
- A systematic program for the experimental exploration of the beam-beam limits at 250 GeV beam energies and their potential dependence on various parameters should be devised before the experiments start for the next proton run.
- Luminosity and lifetime analyses should be based on bunch luminosities and not on the average over all bunches. It would also be valuable to look at the bunch-to bunch variations of the specific luminosity, which should help in separating issues related to intensities and beam sizes.
- Search for a different parameterization of the luminosity decay in terms of a physical model and optimize the integrated luminosity, which would more easily allow for comparisons and interpretation.
- Reinvestigate the possible beam-beam limit at 100 GeV, and its correlation with different parameters, like bunch length.
- Explore the role of bunch length and hourglass effect for β* = 0.5 m at 250 GeV.
- Extract residual crossing angle from transverse Vernier scans, and possibly include angle scans in the luminosity optimization.

- The relative importance of beam-beam tune shift (emittance) and hourglasss effect (β^* and bunch length) should be understood.
- The strategy for setting up the machine in collision and for adjusting Q, Q' and c at the beginning of a fill should be clarified, e.g. either changing the tune before or after the beams are brought into collision, and how the tunes are set and controlled in collision. Tune scans around the nominal working points should be performed.

4. Luminosity

4.1. Electron Lens Development

Findings

Beam lifetime in RHIC drops by order of magnitude as soon as collisions are initiated. The observed luminosity lifetime in the first hour of operation is also some order of magnitude smaller than 12-13 hours lifetime estimated from all other known effects. It was clearly demonstrated that for the bunches which have only one head-on collision (half of the beam-beam tuneshift), the losses are significantly smaller than for ordinary bunches. Further increase of luminosity seems to be limited by the head-on beam-beam interactions and electron lenses were proposed as the way to operation with twice the current bunch intensity (1.1e11/bunch) and two times higher luminosity. The R&D efforts on the electron-lens compensation of beam-beam effects are underway and supported from ARRA funds (1st RHIC electron lens, REL, 4M$) and from AIP (2nd REL, 3.1M$). Both lenses are expected to be built, tested, installed in 2012 and commissioned in 2013. The REL proposal for an operational demonstration has been strongly supported by previous C-AD MACs. The project went thru a number of reviews and, despite delays, appears to be finally set on a right track.

The technique of electron lenses has been developed at Fermilab since late 1990's. The TELs have been studied for operational improvements for several purposes: a) compensation of long-range beam-beam effects (demonstrated factor of 2 improvement in the proton beam lifetime); b) abort gap clearing (factor of about 20 more efficient than any other technique tried); c) hollow electron beam collimation (factor of 3 improvement on the halo particle diffusion speed); d) space-charge compensation (significant reduction of the emittance blowup in a paper study); and e) head-on beam- beam compensation with Gaussian electron beam (no deterioration demonstrated, i.e. factor of 1). The later is because the head-on beam-beam effects on antiprotons are negligible (thus, the electron beam compensation can not gain better performance). Noteworthy, that there are particle tracking tools that explain the Tevatron beam-beam effects and results of the long-range beam-beam compensation operation, and even have sufficient predictive power. The Tevatron experience where no store ever lost due to the TELs operation or action on the beams of protons and antiprotons shows that the lenses can be designed such that fit strict operational requirements of a large SC hadron collider .

The RELs, if successful, will demonstrate for the 1st time operational improvements due to HO BBC. [That is expected to be of interest for the high luminosity LHC.] All the major design decisions have been made and technical specifications on all components developed. Two RELS will be set up in IP10, at the 10 m β-function location. Their main solenoid fields will be set compensate each other.

Comments

Computer simulations of the BBC with RELs performed so far show significant improvement in the luminosity and beam lifetimes at the twice the current bunch intensity if the degree of compensation is about 50% (essentially, only one of two IP is compensated). Nevertheless, the simulations codes cannot predict the current performance of the collider.

The lifetime degradation during RHIC collisions seem to be a complex mix of non-linearities of the final focus magnets, beam-beam interaction, tune and beam-beam force modulation due to orbit vibrations, higher order chromatic effects on tunes and b-functions, coherent oscillations of colliding beams and may be some others. Note that the RELs can compensate only beam-beam effects, therefore, in order to assure success, the other effects must be understood and minimized.

That will require significant effort and nobody can guarantee now that by the start of REL operation, the required understanding will be achieved. IN order not to confuse these effects with REL imperfections, one can urge to build the RELs fully upto the specs, with great attention to details, to assure sufficient diagnostics of the proton and electron beams, and to consider minimal-interruptive regimes of the REL operation.

Recommendations

- Develop hardware, which will make possible operation of the RELs on one of few bunches for initial studies and commissioning stage.
- Suppress low frequency (~10 Hz) beam oscillations to a small fraction of sigma ring wide
- Develop better collider performance analysis tools which will allow fast (in situ) evaluation of the beam transfer and beam-beam effects (see Note #1 below)

4.2. Electron Lens Physics and Simulation

Finding

Significant developments have happened since the previous C-AD MAC: the SimTrack code results have been compared to those from the codes BBSIM and LifeTrac; the codes now do true 6D tracking (that has resulted in an order of magnitude smaller loss rates than in the 4D tracking; many parameters scans have been performed over a range of the betatron phase advances between IPSs, Q”, N_p, N_e, and electron bean size sigma_e and tunes (WPs). In most simulations 2e6 or so turns are simulated, and observable effects are small. So a new algorithm of particle seeding (weighted Gaussian or similar distributions) has been developed. It was shown that the RELs indeed reduce the particle loss if degree of compensation is close to 0.5 and the rms size of a Gaussian electron beam is somewhat (20-40%) bigger than that of the protons. Dynamic aperture analysis also shows ~1 sigma improvements with optimal RELs currents. Despite all the efforts, the simulated beam lifetimes are an order of magnitude better than what is in reality.

Comments

The WP analysis has not beam done – for example, moving bare tunes up right after initiation of the collisions may open extra tune space for operations – , the proximity to the diagonal has not been fully explored, etc.

Effects of the electron beam bends have not been taken into account.

The observed luminosity lifetimes and lifetime reduction at smaller β^* have not been analyzed/predicted by the tracking yet.

For modeling the effect of the electron lens a 6-D kick could be used since a particle entering the lens at an angle should experience a (small) longitudinal effect.

It has not become clear if and how particles with large synchrotron amplitudes are affected by the beam-beam interaction.

Recommendations

- Make a global search for optimum on the working points and parameters of the electron lens. Simulate the beam-beam performance without and with electron lens for the different tunes considered for the next year.
- Study the effects of the long range forces between e-beam and p-beam (in the bends)
- Evaluate numerically and in beam studies the movements of the betatron tune right after/during initiation of the p-p collisions.
- Compare the simulated performance for the present scheme of IR8 compensation with an alternative one where the average effect of IR6 and IR8 is corrected by setting the phase advance between electron lens and the average IR6/8 phase to be a multiple of pi.
- Simulate the effect of the 10-Hz orbit and angle oscillation due to triplet vibrations on the beam-beam performance.
- Explore in simulations if the hourglass effect contributes to the beam-beam performance.

4.3. TEVATRON Electron-Lens Experiences

Finding

Many experiments have been performed during the commissioning of Tevetron Electron Lens (TEL) and the information from TEL is an important input for the RHIC electron lens project for beam-beam compensation. The operation experience of the TEL has shows that the electron lens is very reliable instrument: no run or fill has been lost due to the operation of the TEL and no degradation of the experimental conditions was observed. An electron lens with Gaussian profile is available in the Tevatron since 2009 (TEL2). TEL2 is a pulsed device that can act on selected pbar bunches only

Several results have been given in TEL. TEL is located at a position in which the phase difference condition Dp=npi is not satisfied. Dominant part of the tune shift is compensated, but resonance parts of the beam-beam interaction are not compensated.

In non-collision measurement, beam loss due to the electron lens is not serious, though a loss signal for electron proton collision is seen in a loss monitor. Tune shift due to the electron lens has been measured and the tune shift is consistent with that given by the interaction with a Gaussian charge distribution.

Experiments in collision were performed with the electron lens in three different configurations: a) stores with pbars only, b) parasitic measurements during collisions of 36 on 36 bunches and c) dedicated measurements with 3 on 3 bunches only. Tune spectra were measured for compensated and uncompensated bunches. The measured shift in tune, recovering the beam-beam tune shift, corresponds to theoretical expectations, while the height of the spectrum is enhanced. For the parasitic measurement, the bunches that interacted with the electron lens did not behave worse than those bunches without interaction with the electron lens.

The operation of the TEL and TEL2 showed that the alignment of the lenses is crucial for the compensation of the beam-beam interaction but not for avoiding beam losses.

Comment

TEL2 using Gaussian electron beam distributions begin to give interesting results. Measurements in collision and non-collision conditions agree with theoretical expectation.

The experiments (for test of TEL) were done with lower beam-beam parameter (0.002-0.003) and fewer bunches than during normal operation. We do not need to be afraid of the beam loss due to electron lens in no-collision. Compensation of beam loss due to the beam-beam interaction requires a similar interaction with the electron lens, which may cause beam losses.

Tune spread is narrower and signal height is enhanced for the compensated bunch. The behavior is quite reasonable, because of the reduction of the beam-beam tune spread due to the compensation. This behavior might be disadvantageous for the stabilization of coherent motion.

Recommendations

- Collaborations with FNAL should be continued.
- Beam experiments using aggressive beam-beam parameter >0.01 should be tried with Fermilab's electron lens, measurements with a few number of bunches should be possible without parasitic collisions at Fermilab, if possible.
- The RHIC electron lens project should explore possibilities for operating the electron lenses in pulsed mode so that individual bunches can be treated differently (at least treating the two bunch classes with one and two beam-beam interactions differently).

4.4. Main Solenoid and Corrector

Finding

Very stringent requirements have been specified for the field quality of the main 6-T solenoid of the electron lens. The field straightness should reduce electron-beam position variations to less than +/- 50 microns over a length of 2.1 m. The field quality is specified for field strengths in the range from 1 to 6 T, which is needed to adjust the electron beam size, e.g. for varying proton-beam energy.

No external vendor could be found for the production the superconducting main solenoid. Therefore it was decided to produce the solenoid in the BNL magnet division. This offers better control of the field quality.

Significant efforts were made to manufacture the solenoid with the required good field quality. A set of correction coils, horizontal and vertical, is foreseen to bring the field variations to the required level. Short superconducting transverse correction coils will be installed surrounding the main coil with a maximum field strength of 0.02 T. They are designed to correct field fluctuations due to production errors. Long correction coils with a maximum field of 0.006 T will allow adjustment of the electron beam angle in the collision region within +/- 1 mrad. Positioning the correctors in the outer low-field region has several advantages (quench margin, lower Lorentz forces). Horizontal and vertical correction coils are located in same radial space, allowing for a compact design. Also, on either side of the main solenoid, fringe-field coils are introduced to create the minimum field required outside. The conflicting requirements of high outside field and high field quality inside are met by adding an anti fringe field coil.

At 4.5 K the main Nb-Ti solenoid has a 13% field margin w.r.t. the short sample limit. A quench protection system is under design. The axial forces during a quench are contained by magnet structure and support.

The main solenoid and its correctors represent a demanding magnet system with unique challenges. The planned implementation offers a lot of flexibility.

Comments

Production of the magnets at BNL will provide better conditions for achieving the required field quality. The unsuccessful search for an external vendor has resulted in a significant delay of the electron lens project. The presented concept is appropriate to achieve the required field quality.

Achieving a field straightness of 50 micron for a superconducting solenoid is non-trivial.

Measuring the field quality will require special equipment and could cause additional delay before the magnetic system of the electron lens can be installed. The magnetic field measurements are of high importance as it is planned to install the system immediately in the tunnel.

Magnetic computations can give the linear and nonlinear field contents, which could be used to model the effect of the electron lens on polarization and dynamic aperture.

Recommendations

- Check the accuracy of the proposed vibrating wire method to measure the solenoid-field straightness and compare it to methods used with low energy electron coolers, namely transverse Hall probes and magnetic needle.
- Revise the schedule for installation of the electron lens in the tunnel considering uncertainties in the magnet production.

- Consider using warm correction coils inside the main solenoid in addition to the presently proposed coils for correcting short wavelength field errors.
- Estimate the impedance effect of the electron beam as a function of solenoid field.
- Simulate the effect of the electron lenses on the beam polarization and on the proton dynamic aperture.

4.5. Electron Lens Gun and Collector

Finding

The electron lens requires a Gaussian transverse beam profile. This resulted in a gun design which provides the Gaussian beam with as width σ= 1.28 mm by geometric shaping of the cathode and the anode. This results in high current density which needs a high temperature IrCe cathode. An additional control electrode allows variation of the beam width in the gun. The beam size in the interaction region is achieved by the choice of the ratio of the field strength in the gun and collision region and is variable in the range σ=0.28-0.78 mm. The high magnetic field strength preserves the transverse beam distribution. Gun and collector are designed for dc operation, but pulsed electron current is foreseen for various diagnostics purposes.

The electron beam collector is of cylindrical shape with a magnetic mirror field for reduction of electron losses from the collector. It has an open end for the installation of diagnostics. The design has a lot of reserve with respect to the dissipated power.

Both gun and collector design is based on computer simulations of gun and collector including magnetic field and space charge.

First gun and collector components have been manufactured.

Comment

The design of gun and collector is quite advanced. The design of gun and collector is conservative and the required performance should be achieved reliably. The planned test bench for the electron beam will give the opportunity to commission gun and collector before installation in the tunnel.

Recommendations

- Study the trajectories of hot electrons at the edge of the electron beam which can be reflected in the transition to high magnetic field.
- Operational experience of gun and collector on the test bench will ease the operation of the more complex electron lens system in the tunnel and allow the test of diagnostics equipment, if time allows.
- Prepare operation of the gun for short electron pulses for individual proton bunches as used in the Tevatron lens and test this mode on the test bench.

4.6. Beam Transport in Electron Lens

Findings

The beam transport of electron lens consists of six warm solenoid magnets, normalconducting dipole correctors in the gun and collector bend sections, five short SC correctors to coontrol main solenoid field straightness and two dipole corrector coils. The beam transport is symmetric for the electron gun and collector sides. A high field superconducting solenoid magnet is located in the interaction section. Electron transverse size has to be variable in respond to the proton beam size for 100 GeV and 250 GeV.

Beam size at the interaction line is controlled by the ratio of the magnetic fields at the cathode area and in the superconducting solenoid. To avoid the space charge emittance growth, solenoid field strength is required to be higher than 0.3T along the transport line. The dipole coils for x-y directions control position of the electron beam within +-5mm, and the stability of power supply guaranteed the x-y position in 10^{-4} accuracy.

Two electron lenses for blue and yellow beams will be installed closely in IP10. Beam line is common and the beam separation is 10mm in vertical. This arrangement in which polarity of the solenoid is inverse, makes possible the cancellation of solenoid field for proton beams and thus minimize x-y coupling and spin effects. Centers of the two electron lens are separated vertically 10mm due to the vertical separation of the proton beam. The proton beam is kicked in vertical due to the tilt of the solenoid field at the entrance of the intersection area.

Comments

The beam transport as designed looks quite feasible. It is simple and compact in the combined two-lens system. Preservation of Gaussian distribution at the intersection area is critical issue. Electron space charge force and magnetic field gradient may affect the electron distribution. ExB and grad B drifts.

Recommendations

- Evaluate distortions of the original Gaussian distribution in the main solenoid due to magnetic field gradients in the bends , [ExB] and [grad B x B] drifts.
- calculate proton orbit distortions due to the RELs magnetic fields and design the needed position and angle corrections for the proton beam to target it on the electron beams.

4.7. Electron Lens Instrumentation

Finding

In the present RHIC layout, the nearest BPMs to the electron lens are the BPMs near the two DX magnets. Proton beam orbit control will require more accurate measurements (for both Blue and Yellow beams) than these BPMs can provide. It is envisioned that two more proton BPMs be provided at the ends of the solenoid for the accurate measurement of proton orbits.

Electron beam position measurement is based on modulation of the electron current in the abort gap. A modulator for the gun anode has been designed. The position pick-ups are isolated with respect to grounds as they also have to provide the proper potential for ion clearing which is foreseen along the electron beam path.

A Bremsstrahlung monitor for luminosity monitoring was considered. The presently envisioned arrangement has a marginal counting rate for a rapid monitoring purpose.

Beyond these two devices, various diagnostics were presented for commissioning the electron lens. Various advanced diagnostics systems, e.g. halo monitors, ion collectors, are proposed. Methods to measure the electron beam profile in the collector are in preparation. It is proposed to investigate those techniques on the test bench.

Comment

A plan of instrumentation for the electron lens system was presented. Such a plan is important because a good and well-planned instrumentation is needed to achieve the required quality assurance of the electron lens system. The presented plan included a wide spectrum of envisioned diagnostics and instrumentation devices. Although it is advisable that diagnostics should receive attention in the electron lens design, and the presented list of arsenals represent a systematic survey of the envisioned needs, it does not constitute a properly prioritized list. BPMs at the ends of the solenoid for the electron beam and the loss monitors are critical, some others such as the BPMs at the solenoid for the proton beam should have high priority; while some others may be non-critical or perhaps redundant. The electron beam size is mainly determined by the transport in the longitudinal magnetic field which can be calculated. Deviations from the theoretical distribution seem unlikely or will be difficult to detect.

Recommendations

- Review critically the various envisioned instrumentation need and provide a prioritized list with the required resources. Lower priority devices might not be feasible from resource point of view.
- In the development of this prioritized list, a timeline of design, fabrication, and commissioning should be developed. In this timeline, a strategy for the use of the envisioned test bench be included as an integral part.

5. Committee Members

Machine Advisory Committee

Georg Hoffstaetter, Chair, Cornell

Oliver Bruening, CERN

Alex Chao, SLAC

Geoff Krafft, TJNAF (excused)

Kazuhito Ohmi, KEK

Vladimir Shiltsev, FNAL

Markus Steck, GSI

6. Agenda

Collider –Accelerator Department Machine Advisory Committee
15-17 November 2010 Meeting (MAC-07)

Agenda

Monday, 15 November 2010

08:30 Executive session / discussion

09:00 Begin of morning session
09:00 Welcome (15min) T. Roser
09:15 RHIC upgrades overview (HI & pp) (35+10min) W. Fischer

10:00 Coffee break – Small Conference Room

10:30 Polarized source upgrade (20+10min) A. Zelenski
11:00 Quadrupole jump system in AGS (20+10min) H. Huang
11:30 Acceleration in RHIC near $Q_v = 2/3$ (20+10min) M. Bai

12:00 Lunch – Small Conference Room

13:10 Tour of EBIS (device similar to the electron lenses)

14:30 Orbit effects on polarization in RHIC (20+10min) V. Ptitsyn
15:00 Polarimeter upgrades (20+10min) H. Huang

15:30 Coffee break – Small Conference Room

15:45 Tests for operation with d and ^{3}He (20+10min) W. MacKay
16:15 β^* limitations (20+10min) C. Montag
16:45 Electron lens overview (20+10min) W. Fischer

17:15 Executive session / requests for additional presentations
19:00 Dinner (committee members and presenters)

Tuesday, 16 November 2010

08:30 Executive session

09:00 Electron lens physics and simulations (20+10min) Y. Luo
09:30 Lessons from the Tevatron electron lenses (20+10min) C. Montag

10:00 Coffee break – Small Conference Room

10:30 Main solenoid and corrector (20+10min) R. Gupta

11:00	Electron lens gun and collector (20+10min)	A. Pikin
11:30	Beam transport in electron lens (20+10min)	X. Gu
12:00	Electron lens instrumentation (20+10min)	D. Gassner

12:30 Lunch – Small Conference Room

13:30 Additional presentation on request
14:30 Executive session and report writing

Wednesday, 17 November 2010

08:30 Executive session and report writing

10:30 Coffee break – Small Conference Room

12:00 Lunch – Small Conference Room

13:00 Close-out